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Marine debris ingestion in loggerhead sea turtles, *Caretta caretta*, from the Western Mediterranean

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Abstract

Marine debris represents an important threat for sea turtles, but information on this topic is scarce in some areas, such as the Mediterranean sea. This paper quantifies marine debris ingestion in 54 juvenile loggerhead sea turtles (*Caretta caretta*) illegally captured by fishermen in Spanish Mediterranean waters. Curved carapace length was measured, necropsies were performed and debris abundance and type was recorded. Different types of debris appeared in the gastrointestinal tract of 43 turtles (79.6%), being plastics the most frequent (75.9%). Tar, paper, Styrofoam, wood, reed, feathers, hooks, lines, and net fragments were also present. A regression analysis showed that the volume of debris increased proportionally to the size of the turtles. The high variety of debris found and the large differences in ingestion among turtles indicated low feeding discrimination of this species that makes it specially prone to debris ingestion. Our data suggest that more severe control of litter spills and greater promotion of environmental educational programmes are needed in the Western Mediterranean. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Loggerhead sea turtle; *Caretta caretta*; Marine debris; Sublethal effects; Feeding discrimination; Western Mediterranean

1. Introduction

Sea turtles are currently threatened in all life stages both on nesting beaches and at sea due to human impact. One of the main anthropogenic threats is marine pollution, including marine debris, oil spills and bioaccumulative chemicals (Hutchinson and Simmonds, 1991). Pelagic juveniles are frequently exposed to marine debris in convergence zones and most species are exposed in nearshore habitats where they feed (Bjorndal, 1997). The loggerhead sea turtle *Caretta caretta* seems to be one of two sea turtle species that ingest more debris, in all its life stages, most likely because of its habitat and feeding behaviour (Lutcavage et al., 1997).

The physical and chemical effects on sea turtles caused by marine debris are well described in the literature (National Research Council, 1990; Hutchinson and Simmonds, 1991). These effects may not be lethal at low ingestion levels; however, both can cause side effects that may increase the probability of death (Hutchinson and Simmonds, 1991). An example of such side effects is nutrient dilution, which occurs when non-nutritive items displace food in the gut, affecting the nutrient gain and consequently the growth and/or the reproductive output (McCauley and Bjorndal, 1999).

Information about solid debris ingestion by sea turtles in the Mediterranean sea is scarce (Gramentz, 1988; Venizelos and Smith, 1997). In the Western Mediterranean, data are limited to occasional observations of isolated individuals (Salvador, 1978; Delaugerre, 1987). However, knowledge of the effects of human activities on sea turtles populations from these waters is necessary for two reasons. First, conservation of foraging habitats is considered a priority for population management and survival in sea turtles (Bjorndal, 1999). Western Mediterranean waters provide important feeding grounds for juvenile loggerheads from two different rookeries, the Eastern Mediterranean and Western Atlantic (Laurent et al., 1998). Second, the survival of large juveniles has an important effect on population growth (Crouse et al.,

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1987) and the waters around Spanish Mediterranean islands host a small permanent stock of large juveniles and adult loggerheads (Camiñas and de la Serna, 1995). Tourism and fisheries have deleterious effect on sea turtle stocks in the Western Mediterranean, because of their serious contribution to land-based and sea-based litter spills. The loggerhead sea turtle is currently classified as "vulnerable" by the IUCN (International Union for the Conservation of Nature and Natural Resources, the World Conservation Union), but it was suggested to be considered as "endangered" in the Mediterranean (Broderick and Godley, 1996).

The first objective of the present study was to gain knowledge on debris ingestion by loggerhead turtles in the Spanish Mediterranean waters, through its quantification in a relatively large sample. Second, we wanted to see if there was an ontogenetic trend in the amount of debris ingested testing whether the smaller turtles are more affected than the larger ones. Finally, because it has been demonstrated that these turtles use both benthic and pelagic habitats for feeding (Tomas et al., 2001a), we analysed whether they are exposed to different sources of debris at the bottom, surface and along the water column. Chemical effects of marine debris are not considered in this study.

2. Material and methods

The present study is based on 54 juvenile loggerhead sea turtles intended for illegal human consumption and seized by the Catalan Autonomous Police in Barcelona (Spain). Therefore, specific information about dates and zones of capture is not available. However, it seems that the turtles were incidentally caught by trawling nets on the coast of Northeast Spain (Guitart et al., 1999). This assumption is supported by the size distribution, corresponding with the turtles incidentally captured and stranded at Spanish Mediterranean (Aguilar et al., 1995; Pont and Alegre, 2000), the prey species found (Tomas et al., 2001a) and the similarity of the parasite fauna to other *C. caretta* from the Western Mediterranean (Aznar et al., 1998). Biometric variables were measured during the necropsies (details in Tomas et al., 2001a). Debris and substratum (sand and stones) were collected from oesophagus, stomach and intestine. Total debris and types of debris were quantified by the frequency of occurrence of items longer than 1 cm and the absolute wet volume to the nearest 0.5 ml. We assume that smaller items resulted from fragmentation of larger ones inside the turtles or from incidental ingestion.

Our sample consisted of the size ranges listed in the literature to include ontogenetic dietary shift, from pelagic to benthic habitats (Laurent et al., 1998). However, despite having a relatively wide range of CCL (curved carapace length) (mean $= 49.4 \pm 8.98$ cm, range: 34–69 cm), our turtles seemed to belong to the same stage, as reflected by their dietary composition and feeding behaviour (Tomas et al., 2001a) or by their similar fatty acid composition in fat and liver tissue (Guitart et al., 1999). For this reason, and because this ontogenetic shift does not occur in one step (Laurent et al., 1998; Tomas et al., 2001a), a least-square regression analysis was performed to explore possible tendencies of debris ingestion with body size. CCL (as a measure of size) was used as independent variable and the volume of all kinds of debris was used as the dependent variable. Both variables were log-transformed (+1). All debris, even the wood and reed fragments and seabird feathers cited in the literature as "natural debris", were considered together in the analyses because all them can be ingested equally and can cause similar physical damage and nutrient dilution effects. Statistical analyses were performed with SPSS 9.0 and statistical significance was set at the 0.05 level.

3. Results

Forty-three of the 54 turtles (79.6%) had debris in their digestive tracts. A high number of these turtles showed small amounts of debris (less than 20 ml) (Fig. 1). The outlier of the volume distribution of debris corresponds to one turtle containing 199 ml of sand and 1 ml of a plastic piece. We report more than 10 different types of debris in the 43 turtles with marine debris (Table 1). Twenty-seven (62.79%) of these 43 individuals swallowed more than one type of debris (mean number of types per turtle = 2.51, S.D. = 1.75, range: 1–8). The great differences of debris ingestion between turtles were reflected by the fact that the standard deviations were greater than the mean of volume and number of items for all the types of debris. Anthropogenic debris appeared in 41 turtles,

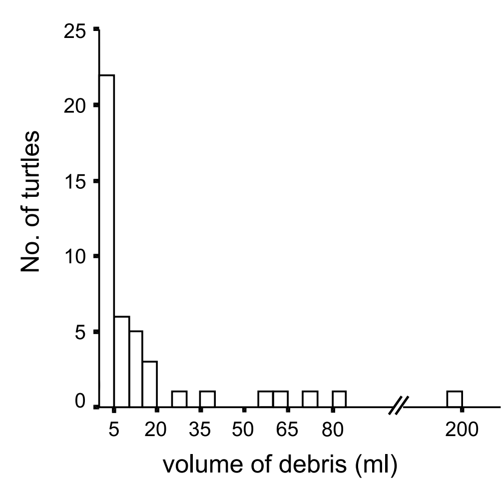

Fig. 1. Distribution of volume of debris in the 43 loggerhead sea turtles with marine debris.

Table 1
Quantification of marine debris found in the digestive tracts of the 54 turtles

Debris	N (%)	V	$(\%)_V$	$\text{mean}_V \pm$ S.D. (range)	NI	$(\%)_I$	$\text{mean}_I \pm$ S.D. (range)
Plastics	41(75.9)	199.5	27.5	3.7 ± 7.02 (0–40)	219	59.8	4.1 ± 6.6 (0–36)
Tar	14(25.9)	115.5	15.9	2.1 ± 7.5 (0–51)	–	–	–
Paper	3(5.6)	5.5	0.8	0.1 ± 0.6 (0–4)	4	1.1	0.07 ± 0.3 (0–2)
Styrofoam	9(16.7)	15	2.1	0.3 ± 0.8 (0–2)	10	2.7	0.2 ± 0.4 (0–2)
Wood and reed	13(24.1)	53.5	7.4	1 ± 2.7 (0–12.5)	68	18.6	1.3 ± 3.4 (0–18)
Seabird feathers	8(14.8)	7	1	0.1 ± 0.4 (0–2)	13	3.6	0.2 ± 0.6 (0–3)
Hooks and lines	3(5.6)	4.5	0.6	0.08 ± 0.4 (0–1.5)	3	0.8	0.06 ± 0.2 (0–1)
Net fragments	6(11.1)	5.5	0.8	0.1 ± 0.3 (0–1.5)	7	1.9	0.1 ± 0.4 (0–2)
Others[a]	4(7.4)	17.5	2.4	0.3 ± 1.5 (0–10.5)	6	1.6	0.1 ± 0.4 (0–2)
Substratum	13(24.1)	301.5	41.2	5.6 ± 28.3 (0–199)	36	9.8	0.7 ± 1.6 (0–6)
Total	43(79.6)	724.5	–	13.5 ± 31.5 (0–200)	366	–	6.8 ± 10.6 (0–59)

(N) number of turtles, (%) frequency of occurrence, (V) volume and $(\%)_V$ volume percentage, (mean_v) mean volume per turtle, (NI) number and $(\%)_I$ percentage of items longer than 1 cm, and (mean_I) mean number of items per turtle.
[a] Other anthropogenic debris.

all of which had plastics varying greatly in consistency, shape and colour. Tar was also common in the digestive tract of turtles, but 44.2% of the tar volume was found in one single animal. Other different types of debris had lower occurrence (Table 1). The high volume of substratum was due mainly to the contents of the digestive tract of two turtles.

Marine debris appeared in the intestine, particularly in the last sections, in higher proportion than in the stomach (77.8% of mean percentage of volume of debris in intestine per turtle vs. 22.2% in the stomach; *t*-test: $t = -5.765$, df $= 42$, $p < 0.001$). Debris entered in similar proportion as the prey items (mean percentage of debris items with respect to the total $= 41.56\%$, S.D. $= 28.59$) and both types of items appeared mixed in the digestive tracts. The volume of all debris increased with CCL (Slope $= 2.76$, $F_{(1,52)} = 8.67$, $p = 0.005$). The slope of the regression line did not differ from 3 ($t\text{-test}_{0.05(52)} = -0.249$, $p > 0.5$).

No significant differences in size (CCL) were found between the turtles with and without substratum (*t*-test: $t = 0.139$, df $= 41$, $p > 0.5$), and no correlation was found between volume of floating plastics and CCL in our sample. ($r = 0.250$, $p > 0.05$).

4. Discussion

The present study reports a high frequency of marine debris compared to other studies with similar sample size of *C. caretta* and other sea turtle species, even if we consider only the anthropogenic debris (Table 2). However, in terms of volume and number of items per turtle, our results agree with other quantitative studies (e.g., Bjorndal et al., 1994). As in the present study, plastic is the most reported debris in marine turtles and other marine animals. Plastic may be disposed of at sea in similar proportions to other types of debris, but it has a high worldwide use, especially by mariners (Laist et al., 1999); moreover, due to its lightweight and its environmental persistence, plastic is the most common human debris found in the sea (Venizelos and Smith, 1997; Laist et al., 1999).

Sea turtles, and especially the loggerhead, demonstrate great resistance to debris ingestion in accordance with the apparent low mortality reported in the literature (e.g., Plotkin and Amos, 1988; Bjorndal et al., 1994; Shaver and Plotkin, 1998). Our analysis showed no lethal effect caused by the debris. No clear evidence of digestive tract blockage was observed during the necropsies, despite the high amounts of marine debris found in six of the turtles (see Fig. 1). This fact, together with the presence of debris preferably in the lasts sections of intestines, indicate that most of the items pass through the digestive tract of the turtles. Only sharp-pointed objects are specially prone to hook up on the gut, as did the 9 cm hook perforating the stomach of one of our turtles, that might have caused its dead (however, it is possible that this turtle was captured still alive by fishermen). Hooks of long-line fisheries represent a great threat for sea turtles, causing thousands of deaths in Western Mediterranean (Aguilar et al., 1995; Tomas et al., 2001b). No physical effects caused by tar were detected during the necropsies. Nonetheless, determining whether marine debris is responsible for the death of sea turtles by digestive tract obstruction is often difficult (Bjorndal et al., 1994).

Sublethal effects caused by debris ingestion, such as dietary dilution, may affect the sea turtle population in the long-term (Bjorndal, 1997). Dietary dilution is caused by a wide variety of non-nutritive items, i.e., anthropogenic debris, but also non-digestible natural debris. This side effect can be significantly detrimental if sufficient gut capacity is appropriated to debris (McCauley and Bjorndal, 1999). In the case of smaller individuals, dietary dilution may represent an important

Table 2
Frequency of occurrence of debris in the sea turtles reported in different studies

Species	Place	*N*	Mean CCL (cm) (range)	%	Reference
C. caretta	Western Mediterranean	54	49.4 (34–69)	79.6 75.93[a]	Present study
C. caretta	Malta (central Med.)	99	(20–69.5)	20.2	Gramentz (1988)
C. caretta	Southern Texas coast	66	(hatchling-109)	47	Plotkin and Amos (1988)
C. caretta	Southern Texas coast	82	(68–18.6)	51.2	Plotkin et al. (1993)
C. caretta	Eastern Florida coast	50	(4.03–5.63)[b]	32	Witherington (1994)
Chelonia mydas	Florida	43	(20.6–42.7)	56	Bjorndal et al. (1994)
Dermochelys coriacea	Bay of Biscay (France)	43	(mostly adults)	51.1	Duguy et al. (1998)
Lepidochelys Kempi	South Texas waters	50	(5.2–71.0)	34	Shaver (1991)

N: number of turtles analysed, mean and range of CCL (curved carapace length) are included when available. % is the frequency of occurrence of debris.

[a] Anthropogenic debris only.

[b] Straight carapace length.

threat because of their faster saturation and their lower ability to increase intake to meet their energetic and nutritional requirements (McCauley and Bjorndal, 1999). Despite of the low amounts of debris found in most of our turtles (Fig. 1), we cannot reject that dietary dilution did occur in our sample because of the similar proportions of debris and prey items found. The comparison of the slope in the regression analysis suggests that the amount of debris increases proportionally to the volume of the turtles (measured as CCL^3). Thus, the amount of marine debris is proportionally equal in our turtles. This result reveals that an important factor determining the amount of debris in the turtles is the CCL, as occurs with prey ingestion. Swallow capacity is higher in the larger turtles because of their longer digestive tracts, their higher energetic requirements and their ability to exploit more dietary resources (Tomas et al., 2001a, and references therein). The question is knowing whether the proportional ingestion of debris to the size produces the same detrimental effect. This may depend on the existence among turtles of differences in their ability to compensate dietary dilution by increasing intakes. More research is needed to determine whether this ability increases with size and age in loggerheads; if this tendency exists, larger turtles would be less affected by ingestion of small amounts of debris (not exceeding the gut capacity) (McCauley and Bjorndal, 1999). Pelagic loggerheads may have this ability limited because of their higher diluted diet, based on low-nutritive organisms, such as jellyfish or salps (McCauley and Bjorndal, 1999). Higher-nutritive prey species, such as fish, cephalopods, crabs and molluscs, were found mixed with debris in turtles of all sizes (within the range of CCL analysed) in the present study (Tomas et al., 2001a). However analyses of nutrient gains are necessary to explore possible increasing in intakes to compensate dietary dilution by debris. Nevertheless, wider range of sizes, including adult individuals, must be analysed to see whether debris ingestion decreases, absolutely or proportionally, when energetic requirements are lower. In addition, retention of debris, which can remain in the gut for months (Lutz, 1990), might increase the observed amounts in larger turtles with larger intestines.

It is well known that pelagic juveniles from all sea turtle species have higher incidence of debris ingestion, because of their indiscriminate pelagic feeding strategy (Bjorndal, 1997). Dietary studies show that all our turtles seem to belong to the same development stage, feeding in all marine strata in an opportunistic way (Tomas et al., 2001a). This was confirmed by our results about substratum and plastic ingestion. Our range of sizes was too small to find absolute or relative differences in debris ingestion between strictly pelagic and larger benthic juvenile loggerheads, and to establish whether the tendency observed is due to the reasons exposed above. We must take into account that Western Mediterranean waters host subadult loggerheads from two different populations exploiting different habitats (Laurent et al., 1998), and our sample might include individuals from both populations.

Several authors have suggested that active debris ingestion occurs by mistake due to its similarity to prey species, such as jellyfish (Mrosovsky, 1981; Gramentz, 1988; Plotkin et al., 1993; Duguy et al., 2000). This hypothesis assumes that the turtles are able to discriminate shape and colour in some manner. However, such hypothesis hardly explains the presence of some debris highly different from any prey species. Our results (i.e., the similar proportions of debris and prey intake, the variety of debris types in the sample and the great differences in debris ingestion between turtles) support that low discrimination exists in the feeding of these animals. Studies from other areas also report marine debris varying greatly in consistency, shape and colour in the digestive contents of loggerheads (Van Nierop and den Hartog, 1984; Delaugerre, 1987; Witherington, 1994).

For a generalist predator such as the loggerhead sea turtle (Tomas et al., 2001a), a strategy of low prey discrimination could be adaptive in unpolluted seas; however, the increase of anthropogenic debris in the sea results in the accumulation of debris in this species, causing important lethal or sublethal effects. Nonetheless, more experimental research in olfactory and visual sensitiveness is necessary to investigate perceptual discrimination by loggerhead turtles.

Due to the high occurrence of debris ingestion by turtles from the Western Mediterranean Sea detected in the present study, a greater control of both land-based and sea-based litter spills in these waters becomes necessary. Also specific educational programmes imparted to beginners and advanced sailors in sailing schools, and also to fishermen, could help to reduce the high prevalence of this particular problem in the Mediterranean sea waters.

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